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1.0 INTRODUCTION

Intermountain Power Services Corporation ("IPSC") has been experiencing a series of burner problems which are defined as follows:

1. Thermal deterioration of the coal flame stabilizers.

2. Thermal deformation of the burner pulverized coal tubes.

3. Burner line coal pipe fires.

In addition to the need to investigate the cause of and correct the above problems, IPSC is exploring the feasibility of lowering current NO_x levels from .45 lb/mmBtu to .3 lb/mmBtu via burner mechanical changes or other means.

At a meeting between IPSC and RJM Corporation personnel on July 14, 1994, it was determined that Computational Fluid Dynamics ("CFD") modeling would be a powerful tool for addressing the above problems. CFD modeling could also be used simultaneously to investigate the feasibility of various in-burner NO_x reduction techniques.

This proposal is in response to IPSC's request to RJM Corporation for a proposal to perform this work.

2.0 UNIT DESCRIPTION

The Intermountain Power generating station has two (2) 820 MW coal fired B&W units. There are 48 B&W, dual register, low NO_x burners in each unit in an opposed firing configuration.

3.0 PROGRAM OBJECTIVES

The program objectives can be defined as follows:

1. To find changes to operating and/or mechanical procedures and setups which would eliminate the conditions currently causing thermal deterioration of the flame stabilizers.

2. Investigate mechanical fixes to the existing pulverized coal tubes which would:

   a. eliminate the ingestion of hot furnace gases during burner out of service conditions, and
   b. provide cooling air to the pulverized coal tube to maintain temperatures below the mechanical deformation point.

3. Investigate the plausibility of and the corrective actions for the possibility that flow separation at the elbows of the pulverized coal pipes causes burner line fires.

4. Determine the feasibility of lowering present NO_x levels to .3 lb/mmBtu by the addition of fuel rich/fuel lean staging devices in the pulverized coal tubes or the secondary air stream.

4.0 PROGRAM ACTION PLAN

A set of two CFD models can be used to address all of the objectives set forth above. The models would employ the very powerful Fluent computational fluid dynamics code. This code is the standard selected by the International Flame Research Foundation and the American Flame Research Council for combustion modeling purposes. The power of the code is reflected in its ability to accurately and visually present flow field, boundary condition, chemical reaction, radiative heat source, and other data which is difficult if not impossible to discern in the real world.

The proposed two models are defined in the following sections.

4.1 Macro Model

The macro model is a three-dimensional model of an Intermountain burner employing a linear furnace geometry which represents the shortest flame path length of any burner in the IPSC boilers. Model boundary conditions will be identical to that experienced in the IPSC boilers and will be structured on real world data supplied by IPSC.

Examination of the macro model will take place in two parts:

Part I - Baseline Model. A baseline model will be used to establish the physics, chemistry, and thermodynamics of the present IPSC burners. Variables to be investigated will include, but not necessarily be limited to, the following:

1. Position of the adverse static pressure gradient boundary in relation to the flame stabilizer and pulverized coal tube in both the in-service and out of service conditions.

2. The burner flow field in in-service and out of service conditions.

3. The existing burner radiative heat flux and temperature profile at full load, combustion conditions.

4. Establish a NO_X baseline.

Part II - Modified Models. It is anticipated that several different models will result from the investigation of possible changes to the baseline model to meet the objectives defined for this program. All of the parameters to be derived as defined under Part I above will be examined as part of this program. The following modified models are expected to be tested by RJM Corporation:

- Model 1 - Parametric study of changes to baseline conditions incurred by modifying the pulverized coal tube to have continuous cooling air in the in-service and out of service condition.

- Model 2 - A model which has altered mechanical setup for design of the burner to eliminate the conditions currently causing thermal deterioration of the flame stabilizers. Pulverized coal tube cooling may be included as part of this study.

- Model 3 - Low NO_X Model - A three model low NO_X study which will investigate the NO_X reductions possible by:

    a. inserting coal separators for fuel rich/fuel lean staging of the pulverized coal flow from the burner.
    b. inserting a fuel rich/fuel lean flame stabilizer into the burner.
    c. a combination of a and b above.

Note: RJM Corporation's experience on conventional coal burners has demonstrated that NO_X reductions up to 42% are possible by employing fuel rich/fuel lean staging of the primary and secondary air streams.

4.2 Micro Model

The micro model is a much more finely detailed model of the pulverized coal pipe. Parametric data from the macro model will be required to set the boundary conditions for the micro model. Conversely, coal separator data will be employed in the macro model for NO_X evaluation. The micro model will be used to:

1. Determine if elbow flow separation causes burner line fires. If flow separation at elbows is the cause of burner line fires, micro model will then be employed to determine mechanical changes which could be installed to eliminate the problem.

2. Resolve the engineering design of the fuel rich/fuel lean coal separator necessary to minimize NO_X.

5.0 COMMERCIAL TERMS

5.1 Program Cost

RJM Corporation will perform the program outlined in this proposal for the prices shown below in accordance with our Fees and Scope of Service and Commercial Terms and Conditions schedules located in the Appendix.

Macro Models

Part I - Baseline Model	$14,000
Part II - Modified Models	12,000
Micro Model	10,000

All prices are quoted exclusive of state and local sales, excise, use or any other taxes. Such taxes, if applicable, will be in addition to the above prices and will be charged to your account. Any taxes assessed to RJM Corporation at a later date will be charged to your account. If the above items are tax exempt, the applicable tax exemption certificate is to be sent to RJM Corporation with your purchase order.

5.2 Program Schedule

It is anticipated that CFD macro and micro modeling will be conducted concurrently. The estimated time for completion is twelve (12) weeks from date of authorization.

5.3 Terms of Payment

Twenty percent (20%) of the contract price shall accompany your written purchase order. Seventy percent (70%) shall be paid in monthly progress payments. The remaining ten percent (10%) shall be paid upon completion of the project.

5.4 Validity

This proposal is valid for acceptance for sixty (60) days.

6.0 APPENDIX

RJM CORPORATION
FEES AND SCOPE OF SERVICE

Personnel Rates

Personnel rates are charged on an hourly portal-to-portal basis as follows:

Principal Engineer	-	$125/hr in 1/2 hour increments
Engineer	-	$100/hr in 1/2 hour increments
Technician	-	$ 60/hr in 1/2 hour increments

Time and Materials Rates

For Time and Materials projects time will be charged at the actual applicable personnel rates. Any required materials or expenses will be billed at cost plus fifteen percent (15%).

Minimum Daily Charges

Minimum daily field personnel charges are eight (8) hours per day per person at the applicable category rate, except for travel day charges which are based on hours actually spent. Weekend travel days are charged on a minimum-daily-charge basis.

Expenses

Per-diem charges per person for field personnel are the greater of $100 per day or $50 above the cost of hotel accommodations. Hotel accommodations shall be charged at cost plus ten percent (10%). Automobile expenses are charged at 35 cents per mile plus tolls. All other travel costs such as air fares, car rental, taxis, parking, etc. are charged at cost plus ten percent (10%).

Air Distribution Analysis and Balancing Programs

Windbox-burner and air distribution programs are conducted on a fixed fee basis which includes all personnel, equipment, travel and per diem charges. Corrective engineering and testing beyond the initial analysis is charged at a per burner rate. For each program, RJM will furnish a budget estimate.

Research and Development Programs

RJM undertakes Research and Development Programs only on a time-and-materials basis due to the uncertainties inherent in such programs. For each such program, RJM will furnish a best estimate budget. RJM will charge against this budget only for time spent and cost incurred. Should a program require funding in excess of the budget estimate, the Client will be notified for written approval of a new budget prior to initiating any work which would incur charges above the old budget.

Long Term Projects

Once each project year all projects are subject to escalation of the budget estimate on a prorated basis in accordance with any revised RJM or subcontractor personnel rates or expense schedules issued in that project year.

Delays and Delivery

All delays in field projects are charged at the minimum daily rate plus per diem and applicable travel expense.

"Not to Exceed" Orders

Under "not to exceed" purchase orders or commitments RJM shall notify the client if additional funds are required to complete the project. RJM shall terminate field services timely to allow personnel to return to the base facility before the limit is exceeded if the client has not authorized additional money. Client shall furnish RJM with an additional written commitment or purchase order prior to RJM's continued field services, engineering or manufacturing after termination on account of "not to exceed" limitations.

Test Work

Fixed prices for test work do not include pre-test or post-test conferences or consulting services follow-up for which RJM standard rates shall apply.

Payments

Terms of payment are twenty percent (20%) with the purchase order. Invoiced payments are due in full within twenty (20) days of the date of invoice. Overdue accounts shall accrue interest at the rate of one and one-half percent (1 1/2%) per month of the unpaid balance thereof and any payment on account thereof shall first be applied against such interest.

RJM CORPORATION
FEES AND SCOPE OF SERVICE

Taxes

All prices are exclusive of state and local sales, excise, use or any other taxes. Such taxes, if applicable, are in addition to quoted prices and will be charged to the Client. Any taxes assessed to RJM at a later date will be charged to the Client. If products or services are tax exempt, the applicable tax exemption certificate shall be submitted to RJM with the Client's purchase order.

Shipping and Insurance

All products are shipped F.O.B. factory. Client shall advise if insurance is required. Shipping and insurance charges will be charged to Client. Client assumes risk of loss of products when shipped and recourse may be sought by Client only against the carrier's insurer. Absent instructions in writing from Client, methods of packing and shipping and choice of carrier and routing shall be determined by RJM in its sole discretion.

RJM CORPORATION
COMMERCIAL TERMS AND CONDITIONS

Quotations - Scope and Content

RJM Corporation (RJM) quotations and proposals shall remain valid for acceptance for a period of 30 days from date of issue. The price quoted is subject to change with changes in project scope, quantities, materials and design. All quotations are subject to conditions listed below under "Delays."

Acceptance and Authorization

No order or change therein or of RJM's proposal is binding on RJM until signed or acknowledged in writing by an authorized representative of RJM at its home office. Proposals or counterproposals shall not be deemed accepted by RJM by mere passage of time. Exception to provisions in RJM's proposal must be set forth in a writing received by RJM and specifically taking exception to such provisions. RJM proposals shall be limited to the contents of written proposals. All drawings, brochures, descriptive matter, weights, dimensions, shipping specifications and the like furnished by RJM with the proposal are approximate only, merely intended to describe generally the product or service and will not constitute a part of any contract.

Commencement

No services or manufacture shall be initiated by RJM until RJM shall be in receipt of a written commitment for the quoted amount together with initial payment of the amount specified below under "Payments."

Delays and Delivery

When RJM is directly responsible for the delay, such as due to failure of RJM test equipment, no delay time or minimum rates apply. Delivery, shipment and installation dates of products are estimated dates only. Delays caused by any conditions beyond RJM direct control, such as partial or complete process shutdowns or irregularities, strikes, floods, fires, power failures, inclement weather, or failure of the client to meet agreed responsibilities, will be billed at standard rates in the case of services and in the case of products shall extend the estimated delivery date. RJM shall in no event be liable for demurrage.

Cancellation

Client may cancel this contract effective upon notice to RJM as provided below under "Notice." Thereupon RJM shall cease all work, cancel all revocable subcontracts, and prepare final billing. For Time and Materials contracts the billings shall be for the time and materials expended by or for which RJM shall have incurred a liability as of the date of cancellation. For Fixed Price Contracts, client shall pay RJM the cancellation charge specified in the proposal or if no such charge shall be specified, such equitable portion of the contract price as shall be equivalent to the percentage of work completed under the contract upon notice of cancellation. For all cancelled contracts, RJM shall be reimbursed for its costs incurred to effect the cancellation.

Patent Infringement

RJM shall defend or settle any claim or suit brought against client to the extent it is based upon an allegation that a product sold to Client in the form manufactured by or to the design of RJM and without regard to the use by client of such product, infringes a United States issued patent, provided such product was not fabricated to the design, drawings and specifications of client. If RJM is notified promptly in writing and given information, assistance and the sole authority to defend or settle, RJM shall pay all costs of defense subject to the limitations of liability above. If the product is determined to infringe, RJM shall at its option: (a) obtain the right to continue using the product, (b) replace the product with a noninfringing product, (c) modify the product so it is noninfringing, or (d) grant client a credit for the depreciated value of the product as returned. The foregoing states the entire liability of RJM for patent infringement.

Proprietary Technology and Data

RJM reserves all rights in and to all invention devices, concepts, processes, products or other patentable or proprietary technology and data conceived or developed by RJM, its employees, agents or subcontractors in the course of performing any contract. Neither Client nor any other person shall have any right to examine or audit RJM's cost accounts, books or records of any kind, or be entitled to have control over or rights in, any engineering or production prints, software, drawings, designs or data which RJM shall in its sole discretion deem proprietary to it. Rights in RJM intellectual property may be acquired on a negotiated basis.

Warranty - Services

RJM represents and warrants that its procedures are generally accepted practices and methods and its personnel are qualified to effect such procedures. Tests are performed on a best-efforts basis and RJM assumes no liability for deviations required by existing conditions beyond its control or field of responsibility. No guarantee or warranty is issued, implied or intended and no responsibility is assumed for testing other than the accuracy of observed results. Should RJM's testing be materially defective, the sole liability of RJM shall be to repeat said test run at no additional cost to Client, provided, however, that said test run was not defective because of a failure of Client to supply critical information or to fulfill responsibilities.

RJM CORPORATION
COMMERCIAL TERMS AND CONDITIONS

Warranty - Products

RJM represents and warrants that (a) products manufactured by it shall be (i) free of defects in materials and workmanship for a period of sixty (60) days from date of shipment to client and (ii) shall conform in all material respects to the specifications for such product agreed upon in this contract. For products not manufactured by RJM the original manufacturers warranty, if any, shall be assigned to client to the extent permitted and such assigned warranty shall be in lieu of any other warranty express or implied. RJM Corporation's sole liability hereunder shall be during the sixty (60) day product warranty period to repair or replace, at its option, products that are defective or non-conforming to agreed specifications. RJM shall have no liability for removal, transportation and replacement of such products.

Limitation and Disclaimer of Warranties

RJM shall not be liable under the warranties hereunder unless:

(a) Client promptly notifies RJM in writing of the alleged deficiency in the product or service and offers RJM a reasonable opportunity to cure such deficiency, and (b) if a product deficiency in an RJM manufactured product, RJM inspection verifies the existence of the deficiency and determines it was not caused by damage or destruction, including any occurring while in shipment, improper installation, testing or repair (including any repair not by RJM agents or employees or otherwise not consented to in writing by RJM), misuse, neglect, or alteration.

THESE WARRANTIES ARE IN LIEU OF AND RJM DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, WRITTEN OR ORAL, INCLUDING THOSE OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR OTHERWISE, AND MAY BE MODIFIED BY RJM ONLY IN A WRITING SIGNED BY RJM IN WHICH IT INTENDS TO BE BOUND.

Limitation of Liability

RJM SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON BREACH OF CONTRACT OR WARRANTY, NEGLIGENCE, OR ANY OTHER MATTER RELATING TO THIS CONTRACT. RJM'S MAXIMUM LIABILITY SHALL IN NO CASE EXCEED THE AMOUNT THAT HAS BEEN PAID TO RJM FOR THE PRODUCT OR SERVICE PRIOR TO THE EVENT WHICH RESULTS IN SUCH LIABILITY OR, FOR INSURED MATTERS, THE AMOUNT OF SUCH INSURANCE.

The prices quoted in this sale were determined in part on the basis that RJM's liabilities and Client's remedies are limited as provided in this Statement and the prices would have been substantially different had those limitations not been agreed.

Governing Law and Disputes

This contract and all questions arising therefrom shall be governed by and interpreted in accordance with the laws of the State of Connecticut.

All disputes arising out of or concerning this contract and the resulting sale shall be determined by arbitration before a single arbitrator in Fairfield County, Connecticut under the rules then obtaining of the American Arbitration Association and any award in such arbitration may be entered in or an application for judicial enforcement of such award may be applied for, in any court having jurisdiction of the party against whom enforcement is sought. The arbitrator shall have no power to award any special, incidental, consequential or punitive damages. It is the intention of the parties irrevocably to submit to arbitration, notwithstanding the contrary provisions of any Federal, State or local law from time to time in effect. RJM shall be entitled to reasonable attorney's fees and costs incurred in the assertion in any proceeding of a claim or counterclaim for goods and services.

Assignment

Client may not assign any interest or right or delegate any obligation hereunder absent the prior written consent of RJM.

Waiver

Failure by RJM to insist upon performance of any term or condition in the proposal or in this Statement shall not constitute a waiver of other terms or conditions or operate as a continuing waiver.

Severability

Failure to deliver any installment due or any defect in delivery or service by RJM constitutes a severable breach only and the Client cannot treat the entire contract as breached unless the goods or services not delivered or defective represent at least fifty-one percent (51%) of the contract price. If an adjustment is made for any failure to deliver, or any defective delivery, or replacement thereof, such default or defective delivery shall thereafter be treated as if it had not occurred.

Notice

Notice hereunder shall be made only in writing to the addresses set forth in the RJM proposal and in the purchase order or equivalent document of Client, or to such other address as may by notice hereunder be furnished from one party to the other, and shall be effective, (a) immediately, if by hand or by facsimile transmission and expressly acknowledged by signature of the recipient, and (b) on receipt, if mailed postage prepaid, registered or certified, first class, return receipt requested.

"Intelligent" Condition Monitoring - The Optimization Approach

By Steven Reilly, DMSI, SKF Condition Monitoring

An intelligent monitoring system does not necessarily use rules or neural nets or genetic algorithms .these are methods for implementing knowledge. An intelligent monitoring system does not have to be large or complex. Its single distinguishing characteristic is that the monitoring system knows what it is trying to achieve, i.e., the objective is embodied within the system. A condition monitoring system that has this built-in intelligence can become a very valuable component of a total maintenance program...it can even help to optimize the entire maintenance function.

Knowledge-based diagnostic systems have been applied in a number of industries throughout the world. These systems have met with varying degrees of success, especially in the field of condition monitoring. The first rule-based systems used in condition monitoring were based on the familiar question and answer format. The objective of these systems was to aid condition monitoring engineers in determining machinery faults, and train the novice in the reasoning process of diagnosing machinery condition.

Although some quite sophisticated knowledge was embedded in the rule bases of these systems, it was time-consuming to produce a conclusion. Also, the somewhat contradictory objectives led to vibration experts being asked long strings of simple questions, and novices in the field of vibration analysis sometimes being faced with questions that would stump an experienced veteran.

A number of factors combined to allow condition monitoring technology to progress to the next stage.

- Better computers - the improving price/performance ratio of microprocessors has created desktop computers with the workstation capability required for intelligent applications.
- Better data collection systems - the current generation of data collectors and on-line data gathering systems have the frequency resolution and high signal-to-noise ratios needed for automatic analysis of narrow band and demodulated spectra. The better the quality of data, the more likely that an intelligent system can produce worthwhile results.
- Better understanding - the methods of condition monitoring have improved significantly over the last five years, with a correspondingly greater consensus about methods of identifying and categorizing faults.

The current generation of knowledge-based diagnostic systems are designed to perform some form of numerical analysis on vibration data, create a set of "features" (extracted spectral peaks and/or trends), then use one or more rule bases to determine the fundamental cause(s) of the vibration signatures.

The underlying objectives of these systems are to efficiently analyze a large quantity of vibration data, separating machines with faults from those running normally, to determine the underlying causes of the faults, and suggest methods to rectify them; and to be useful as a training tool, by explaining the reasoning behind the findings of the system.

These are fairly useful things for a knowledge-based system to do. The system can determine good from bad, and help pinpoint the reasons why a machine is bad. Also, by explaining how it came up with the distinction, it can teach the operator some basic rules for condition monitoring. But does this justify calling the current generation of knowledge-based systems intelligent condition monitoring?

Multi-Parameter Monitoring

The difficulty with monitoring machinery by vibration alone is a lack of synergy. For example, you've got a bearing you think is in trouble. Look at the vibration level...it's a little higher than normal. It could be caused by a fault in the bearing, but there are numerous other possibilities. So you measure the surface temperature of the bearing...it's running a little hotter than normal. Now, you're interested. A synergistic effect is taking place; two pieces of data that may not have seemed like much in isolation are combining to pinpoint a possible problem.

When you get back, you learn that the latest oil analysis on this machine shows that the viscosity of the lubricant has dropped below the minimum acceptable level. Well maybe that bearing won't need to be changed after all; possibly an oil change will bring the vibration and temperature levels down.

The advantage of multi-parameter monitoring is in ordering and prioritizing actions; after all, it's usually better to change your oil than change your bearings. The great difficulty in dealing with multiple parameters is developing the knowledge to make valid use of the data. Application of knowledge to vibration analysis, while not a simple task by any means, has the advantage of a relatively consistent knowledge base; most experts in the industry have some sort of common ground when analyzing a machine. This common ground is not nearly as well developed in other condition monitoring fields such as lubricant/wear particle analysis and process parameter measurements.

Prism^2 Pro v2.00 (SKF Condition Monitoring) has been designed to utilize multiple parameters in diagnosing machine condition. It is a hybrid model-based/rule-based system that can handle vibration, process, lubricant and other data sets (Figure 1). The use of a knowledge editor (Figure 2) allows the addition of further knowledge to the system. This enables the end user to custom tailor the system to handle a wide variety of machines, especially those machines with unique operating characteristics.

The combination of multiple data sets and configurable knowledge bases lets us take advantage of the synergy that occurs when several predictive maintenance technologies are employed, even if the knowledge bases for a measurement type are not generally available.

Once again, we are brought back to our fundamental question - what is the objective of condition monitoring, and how do we embody it into a system?

The objective of condition monitoring is to allocate maintenance resources to produce an optimized mix of predictive, planned and breakdown maintenance. An intelligent condition monitoring system must not only make suggestions about the state of machinery, but about the actual process by which we maintain the machinery. In other words, the system has to completely embody its own cost/benefit analysis, and to alter the mix of maintenance methods to maximize that benefit to cost ratio.